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Empower saving energy into smart homes using a gamification structure by social products

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Abstract—The users' behavior in a house impacts the amount of electrical energy consumption in the electrical products of the household; therefore, energy consumption can be optimized by using sense, smart and sustainable products (S³) as Social Products (SPs) for saving energy in the housing. The SPs communicate between devices and consumers through game design elements known as gamification that can yield behavioral changes in users. Furthermore, behavioral models can shape human behavior to motivate the individual to achieve a specific target, like saving energy. For the energy consumption reduction in households, it is proposed a structure with SPs that uses a gamification Human Machine Interface in each device to communicate between products and consumer in a Smart Home (SH). In this descriptive paper, it is proposed a three-steps structure that applies to every social product. First, it requires the classification of the type of end-user, the behavior, and usability problems when the product is deployed. Then, through the analysis of fuzzy logic, either type 1 or type 2, it is proposed which housing gamification elements best tailors the interface for each appliance. Finally, the application sends stimulus to individuals to test their performance and motivation to use each social product. After every social product has its proper gamification, it is possible to have interconnected SPs to get a Gamified SH. Besides, this Gamified SH could communicate with other Gamified Smart Homes to obtain a Gamified community.

Keywords—Social Products; S³ Products; Smart Home; Gamification; Gamified Smart Home; HMI; fuzzy logic; structure

I. INTRODUCTION

Energy consumption in buildings, including housing, represents 40% of the total energy consumption in the United States [1], whereas in the EU households represent 25% of the total energy consumption [2], it is mainly due to the users' behavior that has brought environmental problems, reduction and availability of energy [3]. In SH, the metering of electrical devices is used because of the facility to measure consumption and identify users profile [4]. Thus, Fig. 1 shows how household appliances like Smart TV, electric stove, coffee maker, interior lighting, washing machine, refrigeration, and smart thermostats can be part of the SPs. The Social Products are emerging as a concept to design and use actual technologies
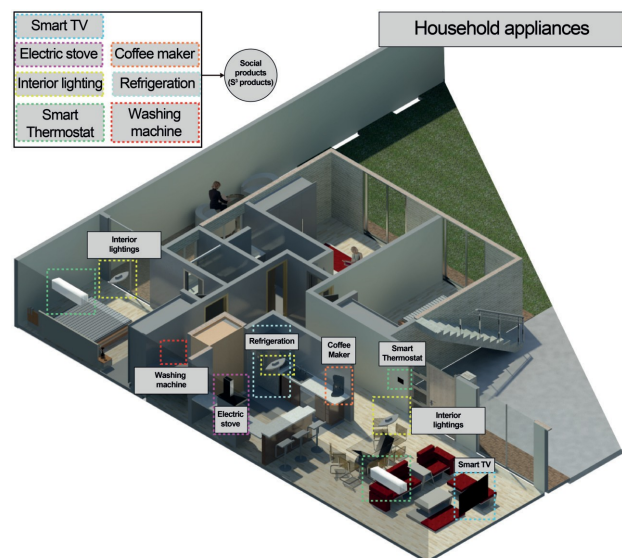

Fig. 1: Household appliances able to become SP in a SH.

to develop a sense, smart and sustainable products known as S³ Products to communicate between consumer-products and interact between products. So, they can be implemented in the household appliances in a Smart Home [5], [6].
To promote the SPs in a Smart Home is required to know which behavior and usability problems are present when the smart device is used, as well as to involve residential energy users in the process of planning, implementation and monitoring of the energy usage. In that sense, Ponce et al. [7], [8] pointed out behavior and usability problems when products are deployed, which can apply to other household appliances in the Smart Home, too. The Transtheoretical Model [9], Fogg Model [10], and Theory of Planned Behavior [11] are models that shape users' behavior to produce a change in their habits, for example, to reduce energy consumption in households.

Besides, the use of game design elements in products and services called gamification [3], [12] is emerging as a way to engage and motivate individuals based on their internal and external motivation to realize specific activities. However, fuzzy logic can represent human reasoning and human decisions through a set of *If-Then* rules [13]. In this regard, the authors proposed a first approach for a model that uses Artificial Neural Networks and Fuzzy Logic to classify the level of ecological behavior engagement in the costumers of a Smart Thermostats as an S^3 Product [14]. Furthermore, the authors also proposed a framework the uses a fuzzy logic system decision to solve behavior and usability problems for connected thermostats in a gamified tailored interface [15]. However, the literature review reveals that there is no evidence of using global gamification in Smart Homes that uses fuzzy logic to solve behavior and usability problems for Social Products. Therefore, it is proposed a structure that considers in each household appliances a fuzzy logic system with gamification structure that can communicate between products and product-consumer in the Smart Home. Moreover, this structure could be used in a community where the household managers can track and promote energy savings in population.

This paper is structured as follows; in section 2, it is described the methodology required to propose a tailored gamified Human Machine Interface structure for SPs. In Section 3 it is proposed the three steps structure using as a basis the gamification and serious games concepts, as well as, fuzzy logic type 1 or type 2 to offer a tailored Human Machine Interface suitable for Social Products. In section 4, it is presented a mock-up of the structure that can be used in a mobile phone or tablet. Section 5 offers the scope of the structure, its advantages and disadvantages. Finally, in section 6, conclusions are given.

II. METHODOLOGY

A. Gamification in housing

According to Chou [16], gamification is 'the craft of deriving fun and engaging elements found typically in games and thoughtfully applying them to real-world or productive activities'. Besides, he created the Octalysis framework formed by eight-core drives: Epic meaning and calling, Development and accomplishment, Empowerment of creativity and Feedback, Ownership and possession, Social influence and relatedness, Scarcity and impatience, Unpredictability and curiosity, and Loss and avoidance. This structure analyses and builds strategies to make real-world applications engaging by using extrinsic, intrinsic, positive and negative motivation. Moreover, Stieglitz, Lattemann and Ro [17] suggest that any gamified application requires an achievement system structure to engage successfully end-users. This achievement system requires an identifier, an achievement unlocking-logic and game-related, external and achievement system-related rewards.

On the other hand, Giessen [18] considers Serious Games as designing games for non-entertainment purposes with an explicit educational purpose to achieve goals. Fijnheer and Oostendorp [19] analyzed several design methodologies to finally propose two steps guideline that uses gamification elements to design a household energy game. The first step is the review of the state of the art of which are the most common elements used in games. The second step is to develop a Game and Dashboard Prototype. This methodology could be improved by considering the use of Social Products to connect the housing through a gamified smart home strategy that can test a user's improvement and shape user's behavior to produce energy and money-saving.

Peham, Breitfuss and Michalczuk [20] propose the 'ecoGator' gamified application to support consumer awareness for energy-efficient purchases through a gamification strategy based on rewarded activities. However, this application does not consider an interaction between products and the end-user.
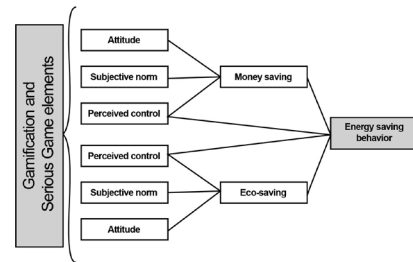
B. Behavior models and type of users

Fig. 2: . Proposed energy saving behavior model derived from TPB Model [21].

Ponce et al. [5] propose to use a gamification strategy in the HMI to shape consumers' behavior. Regards, several behavior theories, and models have been proposed to change users' habits to produce a real change. The Transtheoretical Model [9] has been applied to change behavior in areas like behavioral medicine, residential customers' water use behavior and residential customers' energy-related behavior; this model classifies the process of behavior change into six stages: pre-contemplation, contemplation, preparation, action, maintenance, and termination. The Fogg Behavior Model [10] expresses that motivation, ability, and prompts elements must converge at the same moment to have a change in behavior. The Theory of Planned Behavior (TPB) [21] is a research tool where the behavioral intention and attitude of a person about a specific behavior are determined by being able to understand three pairs of determinants: behavioral belief - attitude, normative beliefs - subjective norm, and control belief - perceived behavioral control.

As the TPB model is used for pro-environmental behaviors [21], in Fig. 2 it is proposed to use economic saving and eco-saving behavioral intention to promote energy-saving behavior in SH, so a gamification technique is applied to motivate them. Moreover, when smart devices in household appliances are deployed, the literature review suggests classifying users according to their personality traits [14], [15], [21], [22]: Openness, conscientiousness, extraversion, agreeableness and neuroticism; to their economic activity, and qualitative evaluation of energy end-users [7]: Green advocate, traditionalist

Personality trait	Characteristics
Openness	Tend to have environmental engagement.
Conscientiousness	Are somewhat positive regarding environmental engagement.
Extraversion	Do not appear to have a significant impact on behavior.
Agreeableness	Tend to have environmental engagement.
Neuroticism	Experience significant environmental concern.

TABLE I: Personality traits and characteristics [22], [21].

End user segment	Characteristics
Green advocate	Users are interested in technologies and are energy aware.
Traditionalist cost-focused	Users have limited interest in new technologies. Energy-saving behavior is motivated by cost-saving.
Home focused	Users are interested in home improvement efforts and concerned about saving energy and reducing cost.
Non-green selective	Users are selective at energy-saving appliances, focus on set-and-forget inventions, and are not energy aware.
Disengaged	Users are not interested in new technologies and are not concerned about the environment.

TABLE II: Energy end user segments and characteristics [7].

Energy target group	Characteristics
Early adopter	They are new technology enthusiasts and participate in social media communities. They are not energy aware.
Cost-oriented	They take care of their household and focus on cost-oriented behaviors. They try to adopt a sustainable life-style.
Energy-conscious	They attempt to lead a sustainable lifestyle. They are energy aware. They use smartphones and are not necessarily active on social media.

TABLE III: Energy target groups and characteristics [20].

(MF). 2. Inference linguistic rules are proposed with the help of experts; they have an antecedent IF part and consequent THEN part. 3. Defuzzification determines the optimal values outputs, i.e., the system passes the fuzzy values into crisp outputs throughout fuzzy inference methods. In step two, the inference model used in this paper is the Mamdani Inference Model and the Sugeno Inference model to determine which inference model has the more precise output values or if there is any significant difference between both models [13]. On the other hand, the T2FL is the extension of the T1FL, where additional information is provided for the secondary MFs; this fuzzy logic deals with experts opinion by showing a Foot Of Uncertainty (FOU) related to each expert advice. The FOU comprehends an Upper Membership Function and a Lower MF. Furthermore, before the third step, it is used a type reducer that takes the Type 2 output sets into a Type 1 set [24].

III. PROPOSED STRUCTURE

It is proposed to fill the gap between the information provided by the household appliances, the user's expectations, and the environmental impact through a Human Machine Interface that solves the usability and behavior problems proposed by Ponce et al. [7], [8]. Fig. 3 shows, based on Fijnheer and Oostendorp [19] design steps, the proposed three-step structure (knowledge base, fuzzy logic and evaluation) for each Local Gamified Social Product. In conjunction conforms the Global Gamified Smart Home that communicates with other Smart Homes to get a Global Gamified Community where users who spend most of the time in the household participate between each other to promote saving energy and money at the same time they are shaping their behavior.

A. Knowledge base

Fig. 4 shows a diagram derived from the Achievement Structure [17] that additionally considers the interface elements part and the customer part. The customer part includes the type of users according to their personality traits [22], energy end-users [7], and energy target groups [20] collected from the literature review and used by the authors in [14],
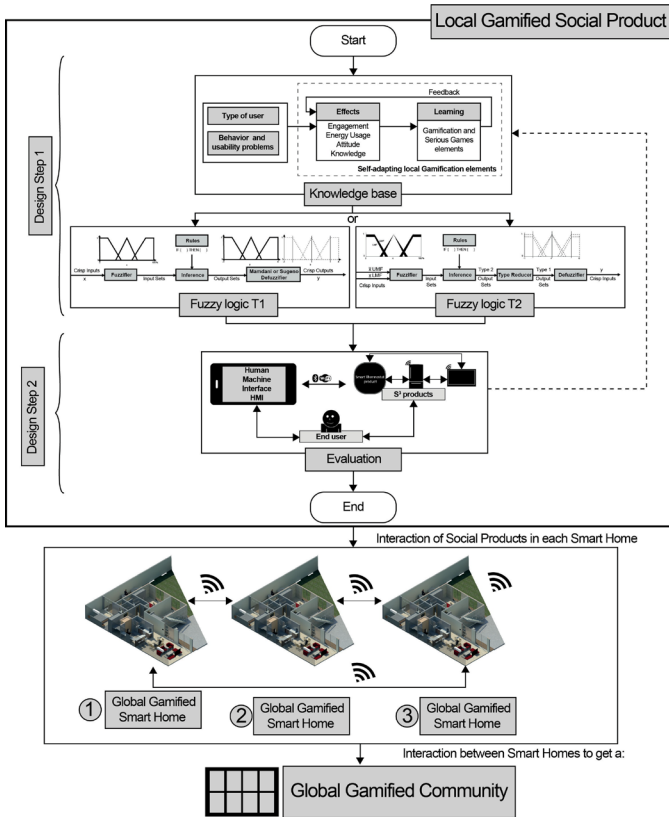
cost-focused, home-focused, non-green selective and disengaged; and to energy target groups [20]: Early adopter, cost-oriented and energy-conscious. Thus, tables I, II, and III describes those types of users.

C. Fuzzy logic Type 1 and Type 2

Fuzzy logic proposes to model uncertainty based on linguistic variables related to human reasoning instead of using numerical values. L. Zadeh proposed this theory in 1965 [23] where a class of object belongs to a fuzzy set with membership grades from zero to one and inference rules that do not need a mathematical model of the real system but rules proposed by experts, polls or consensus-building [13]. There are two types of Fuzzy Logic, Type 1 Fuzzy Logic (T1FL) and Type 2 Fuzzy Logic (T2FL). T1FL has three steps: 1. Fuzzification is based on a process where variables have an uncertainty metalinguistic degree and are classified in fuzzy sets, for instance, Attitude variable = High, Low, Medium, where those values have a range from 0 to 1 into the Membership Function

Fig. 3: Proposed structure of Social Products in SH.

Fig. 4: Gamification and Serious Game Achievement diagram.

B. Fuzzy logic phase
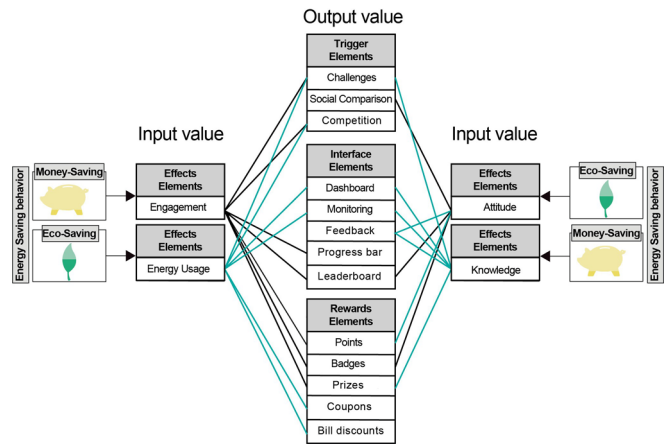
Fig. 5: Relationship between input and output gamification elements.

[15]; each of the achievement phases is proposed to solve the usability problems detected in each Social Product. In that sense, the interface of an interactive system influences the user's decisions, expectations and motivations so the interface should be useful, easy to use, and designed to be enjoyable and exciting [12]. Furthermore, for the Interface Elements, the Octalysis framework helps as a guideline to consider which elements of every Core Drive require each type of user to engage and motivate the user to save energy and money with as well as five elements that AlSkaif et al. [12] propose for an energy application: 1. Information provision, such as statistics, data-driven messages and tips, can give residential customers a clear view of their energy-related behavior and allow them to understand how their actions impact the amount of electricity they use. 2. A rewarding system based on their energy consumption behavior, effort and impact, can incentive users to take specific actions and increase satisfaction. 3. Social connection can make energy applications more fun and appeal to residential customers if they are displayed in the form of social competition, collaboration or energy community; 4. An interactive interface that users can perceive it useful, easy to use, enjoyable and exciting; 5. Performance status that allows following the progress of customers through points, badges and levels to change the way they behave and interact with an application; 6. Feedback, according to their psychological and behavioral outcomes.
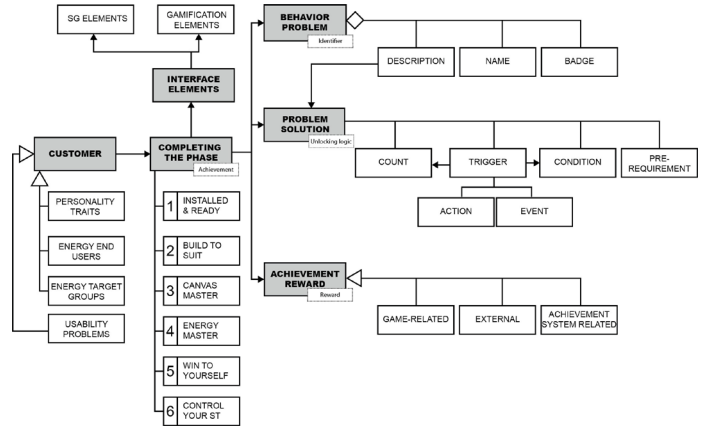
In this phase, from the knowledge base, it is proposed Mamdani Type 1 Fuzzy Logic, Sugeno Type 1 and Type 2 Fuzzy Logic to analyze the most accurate outputs values to later proposer the tailored HMI for each user. Accordingly, Fijnheer and Oostendorp [19] propose to measure the effects of engagement, knowledge, attitude and energy usage elements in terms of percentages; thus, those effects are considered as the input values for the MFs. Besides, energy behavior in end-users are shaped through the engagement and knowledge elements to promote money-saving energy behavior, and through the energy usage and attitude elements to promote the eco-saving behavior proposed in Fig. 2. Whereas the gamification and serious game elements proposed in Section A (Knowledge base) are divided into three groups from the Achievement Structure proposed in Fig. 4: Trigger, Interface and Reward Elements; thus, those groups are considered as the output values for the Membership Functions.
Fig. 5 displays the relationship between the input and the output elements of the gamification structure: 1. Engagement: Challenges, Competition, Progress bar, Leaderboard, Points,

Badges, and Prizes; monitoring the player's behavior while the application is being used is a manner to determine if the user is engaged [19]. 2. Energy Usage: Challenges, Competition, Dashboard, Monitoring, Coupons, and Bill Discounts. Through the monitoring of electrical energy meter, it can be measured what is happening with energy usage [19]. 3. Attitude: Social Comparison, Leaderboard, and Badges to measure if the user has a change in attitude toward saving energy and money [19]. 4. Knowledge: Challenges, Dashboard, Monitoring, Feedback, Points, Prizes can be measured with in-game quizzes [19].

Fig. 6 shows the FL proposed for each Social Product; a) has the membership functions for the Mamdani T1FL inference model; b) the membership functions for the Sugeno T1FL inference model; c) the Sugeno T2FL inference model showing the foot of uncertainty; d) shows the Frontal Panel developed in Labview for the T1FL and T2FL set. The T2FL set with is done with the IT2-FLS Matlab/Simulink Toolbox [25]. Eighty-one rules are used to test the fuzzy system. Besides, the output values are measured with the Semantic Differential Scale to detect any behavior change through a scale that goes from 1 to 7, being 1 the lowest value and 7 the highest [26].
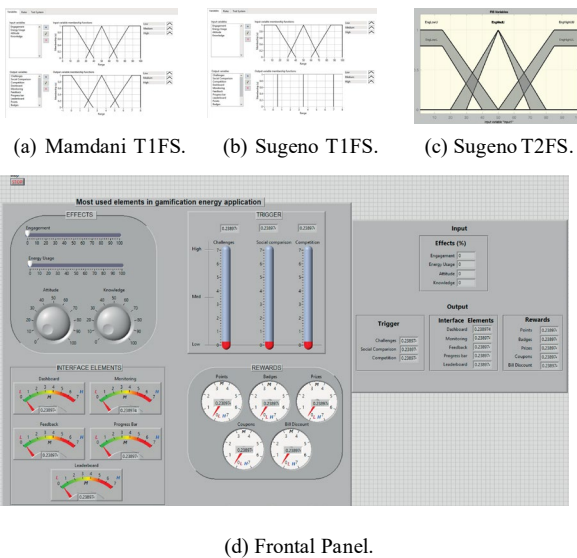

(a) Mamdani T1FS. (b) Sugeno T1FS. (c) Sugeno T2FS.

(d) Frontal Panel.

Fig. 6: Proposed fuzzy system to test each Social Product.

C. Evaluation phase

For the Gamified HMI and based on the type of user, behavior, and usability problem it is proposed an end-user with a tendency to experience fear and sadness emotions, impulsive, stressful and bad-tempered (neuroticism personality trait). This individual is a selective energy saving (non-green selective end-user) and concerned for a cost-oriented way of life with the characteristic of mostly being connected through smartphone and social media user (cost-oriented target group). As well, with the behavior problem of a user whose interests are different than saving energy and the usability problem of the information presented in the interface is complicated

to search because it is not focused on the user's task to test the Fuzzy logic phase [7], [8]. As a result of this type of user, the input values have the following characteristics: Low engagement, Medium Energy Usage and Attitude, and High Knowledge. Fig. 7 shows the results in each type of inference model: in (a) the T1FL Mamdani inference model has more precise values than T1FL Sugeno inference model (b); however, as the T2FL uses a FOU (c), it shows the most accurate values. These precise values help to show the three inferences models globally.

For the T1FL, the Mamdani inference model (a) is more accurate than the Sugeno model (b); even if the Mamdani model considers the area of the MF that the Sugeno does not, the difference is not significant because both results are within the range of the MF's output values. Regarding the Sugeno Type 2 FL (c) with the models of Type 1, as T2 uses FOU, it shows a broader range of output values, that helps to notice which values are closer to the High or Low value and which are in the Medium value. However, the difference between the three models is not critical, so any of these three models can be used to propose a custom interface; therefore, it helps as a guide for the designer.

The input value for this end-user has low engagement, as well as the output values show a little interest in progress bar but high interest in prizes, with average values for the other output elements, the interface is focused on the high and medium output values. It means that the application gives the user more Rewards based on how much does the user know about the benefits of energy-saving and money of the SPs.
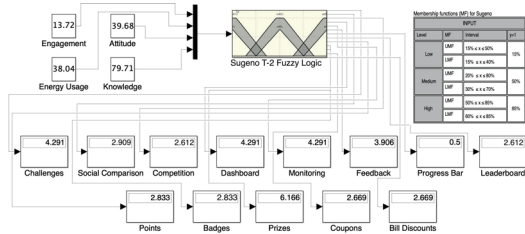
IV. RESULTS

In Fig. 8(a) it is displayed the communication between the social products in a house with the interface. In the SH the SPs communicate between products and the user, the user has specific characteristics of how Eco-Saving and Money-Saving are, so through the fuzzy logic decision, it is proposed the HMI that best tailors to this user; thus, the HMI is in continuous communication with the SH. Is that so, in Fig. 8(b), based on user's interests, a *My Social Products* layout HMI is proposed where the Global Gamified SH application is displayed for each local gamified Social Product. In the top left layout it is displayed weekly energy and money-saving monitoring. So the user can visually monitor any self-improvement. Besides, the display shows an example of four types of social products available in that Smart Home, for instance, inside the Smart Thermostat button (Fig. 8(c)), the interface displays a tailored Dashboard [15]. On the interior layout, the feedback rectangle (right side) is composed of three options: 1. Inside the Tips button, HVAC and Dwelling sections advise of how to improve the use of air conditioner and the housing; 2. The Learn More button has the purpose, by using Serious Game techniques like virtual scenarios, to make the user understand how does the Dashboard works and the use of the Smart Thermostat can be improved; 3. In the BLOG option, the user can share comments about the application. Finally, on the Monitoring block (left side), the elements displayed are the Setpoint degree
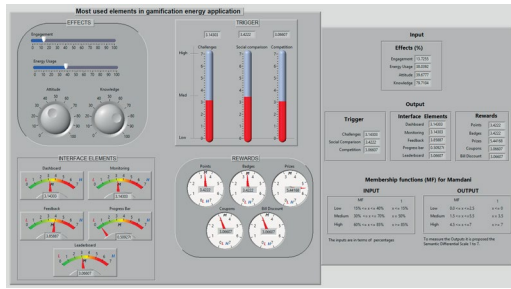
(a) Mamdani T1FL test result in Labview.
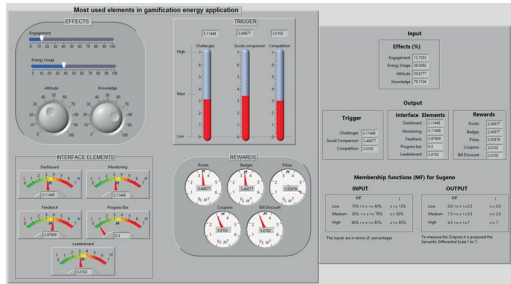
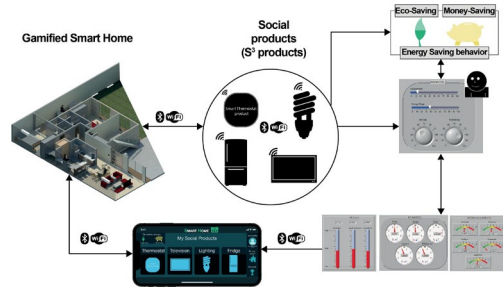(b) Sugeno T1FL test result in Labview.

(c) Sugeno T2FL test result in Matlab Simulink.

Fig. 7: Fuzzy test results.

(a) Social Product Communication.

(b) Global Gamified HMI in Smart Home.

(c) Smart Thermostat Dashboard elements.

Fig. 8: Tailored HMI of the SP for the SH.

temperature, HVAC mode (cool, fan, heat, auto), the schedule (home, vacations or custom) and the Historic button. Inside it, the user can track how much energy and money is using and saving, on the central part shows a graphic in day, week, month and year mode so that the user can monitor his/her energy behavior.
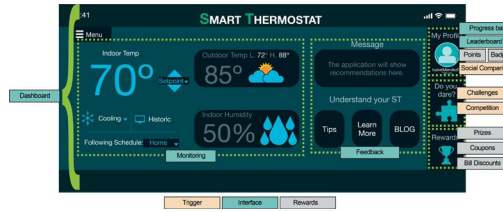
V. DISCUSSION

In this paper, based on the two Design steps of the Household energy game design methodology [19], a structure made up of three phases is proposed: Knowledge Base phase, Fuzzy Logic phase, and Evaluation phase. Finally, in the evaluation phase, the interaction produced between each social product and interface test the levels of local engagement, energy usage, change of attitude and knowledge in terms of how much energy and money savings are the user achieving. Nevertheless, this structure can be improved by automating the process of knowledge base with an artificial neural network that collects the information of the user and the local gamification to feed this base. By proposing which gamification and serious game elements require the customer, the knowledge base can

strengthen with all these values to offer more than one usability and behavior problem-solving. With the proposed interface, the behavior problems found in Ponce et al. [7] can be solved by giving the user the required gamification and serious games elements. Thus, the end-user learns the benefits and advantages of each social product. To solve physical usability problems found in Ponce et al. [8], the designer of the thermostat, can propose a design based on what the proposed structure of Social Products suggests. The idea of this layout is to motivate and engage the user through gamification elements that help the user become energy awareness and bill saver.

VI. CONCLUSION

This paper describes a structure that integrates gamification, serious games, and fuzzy logic to save energy and money to improve usability problems in Social Products to get a Gamified Smart Home. Furthermore, according to the FOU in the selection system, the fuzzy logic system could be changed from type 1 to type 2, so, the proposed interface allows tackling uncertainty problems in a better way. On the other hand, state of the art indicates that it does not exist an interface that uses gamification and serious game with a fuzzy logic decision system that allows the user to save energy, save money and solve behavior and usability problems. Thus,

this paper proposes to integrate this framework in each social product of the housing to develop a Global Gamified Smart Home that can be connected with similar Smart Homes in the neighborhood. Moreover, this framework can be used as a guideline for product designers to propose Social Products considering a smart, sensing and sustainable product that fills the gap between users' expectations and products deployed.

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